

# **FORCING MECHANISMS FOR DESTRUCTIVE SEICHES IN THE BALEARIC ISLANDS**

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## **LONG-TERM GOALS**

Our long-term goals are to increase understanding of the role played by internal waves in coastal seiche generation globally and to apply this knowledge to improve hazardous seiche prediction.

## **OBJECTIVES**

The objectives of the present effort are to investigate the forcing mechanisms for the large-amplitude, destructive seiching events that occur at Ciutadella Harbor in the Balearic Islands (western Mediterranean) and, based on the results, to develop methodologies for providing advance warning of those events.

## **APPROACH**

We developed a cooperative field study in collaboration with scientists at the University of the Balearic Islands (UBI) to gather data from Ciutadella Harbor and vicinity to test hypotheses concerning the forcing of the destructive seiching events (e.g., forcing is primarily by meteorological processes; forcing is primarily by internal waves). A sea level and water temperature recorder was established in the harbor, a mooring with water temperature and pressure sensors was established offshore in Menorca Passage, and wind data were obtained from the Spanish meteorological service.

## **WORK COMPLETED**

We have collected one-minute sea level and water temperature data at Ciutadella Harbor for 1123 days during 1992-1996, water temperature and pressure data from the offshore mooring for four months during 1994, and surface wind data for the same four-month period. Analysis of these data was completed in 1997.

## **RESULTS**

Ten-minute (resonant) oscillations of Ciutadella Harbor were almost always discernible from the sea-level data, but seiches larger than about 0.5 m had a pronounced seasonal distribution closely correlated with the seasonal distribution of surface water (upper 50 m) stratification (fig. 1). Extreme seiching events (daily mean activity greater than 50 percent of the total range for all 1123 days) occurred only four times during the observation period, once each during 1992, 1993, 1994 and 1996. Maximum seiche oscillations during these events ranged between 1 and 2 meters.

The four extreme events each occurred under unusual and remarkably similar tidal conditions, near-apogean neap tides. The four-month period for which we had wind data included the 1994 event. The steadiest episode of strong southeasterly wind of the entire four-month period immediately preceded the extreme seiching event. Ciutadella fishermen have often reported a similar relationship between southeasterly wind and destructive seiche events.

## **IMPACT/APPLICATIONS**

Previously, it was thought that the role of internal waves in large-amplitude seiche generation was restricted to those cases in which seiches are forced by tide-generated internal waves. The new results provide evidence that both tides and internal waves play an important role even when the initial forcing is provided by atmospheric processes. In such cases, application of this improved understanding should produce improved predictions of destructive events.

## **TRANSITIONS**

Prior to the 1998 "seiche season" we expect to be able to provide our colleagues at UBI dates of the approximately 6 periods in 1998 when water stratification and tidal conditions would "allow" for extreme seiching events. We would expect such an event on any of those dates if strong and sustained southeasterly winds also occur.

## **RELATED PROJECTS**

Julio Candela and Richard Limeburner (Woods Hole Oceanographic Institution) are studying flows through major passages of the western Mediterranean. Clint Winant and colleagues (Scripps Institution of Oceanography) have obtained interesting measurements of shoreward propagating internal waves over the shelf off southern California.

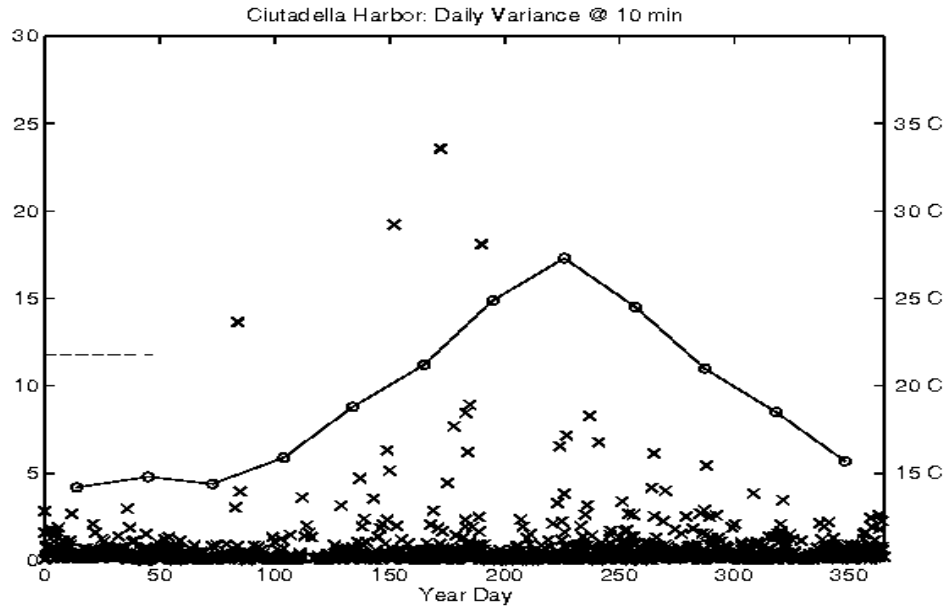


Figure 1: Relative daily sea-level variance (left axis) at Ciutadella Harbor for periods between 9 and 12 minutes ('x') plotted against year day. This plot represents data for 1123 days. Dashed horizontal line on left side indicates value of 50% of the total range of daily variance and separates the four days of exceptional seiche activity from the remainder. At relative variance values of approximately 3, seiches with ranges as large as 0.5 m may occur; at values of about 10, seiche ranges as large as 1 m may occur. Circles connected by solid lines indicate the mean monthly harbor surface water temperature during the study period and refer to the vertical axis on the right side of the figure. Since offshore water at a depth of 50 m maintains a relatively stable temperature of approximately 13 degrees C, these data indicate monthly changes in thermal stratification.

